Ecosystem Expert Panel

During the period of the fishery, has the carrying capacity of the ETP for dolphins declined substantially or has the ecological structure of the ETP changed substantially in any way that could impede depleted dolphins stocks from growing at rates expected in a static system? Or has the carrying capacity increased substantially or has the ecological structure changed in any way that could promote depleted dolphin stocks to grow at rates faster than expected in a static ecosystem?

Over the past fifty years, approximately 6 million dolphins have been killed in the Eastern Tropical Pacific purse seine fishery for yellowfin tuna, resulting in the depletion of three stocks of dolphins. The Ecosystem Expert Panel has been asked whether or not substantial changes in the ecosystem have occurred during this period that may have affected the demographics of three stocks of depleted dolphins. To answer this question, I have reviewed the results of research conducted by scientists from NOAA Fisheries on the ecosystem of spotted and spinner dolphins in the ETP. I was impressed by the quality and quantity of research directed at this difficult question and appreciative of the assistance of NOAA Fisheries scientists in interpreting the results of this work.

A variety of potential changes in the structure and function of the ETP ecosystem have the potential to affect the demography of depleted dolphin stocks. These include both bottom-up processes, in which the dynamics of dolphin populations are regulated by those of their prey, and top-down processes, in which their dynamics are modified by the actions of predators and competitors. A great deal of information, obtained over an appropriate time scale, is required to evaluate the probability that such changes have occurred, and in such magnitude to substantially impede or promote the growth rates of dolphin populations.

Unfortunately, we do not have a sufficient understanding of the structure or function of the ETP ecosystem to answer this question. Our knowledge of the ecological interactions of dolphins and other ecosystem components, including yellowfin tuna, is so rudimentary that in most cases, we cannot predict whether a particular environmental change might promote or impede the population growth of dolphins. Furthermore, we do not have a sufficient time-scale of observations to allow tests of hypotheses regarding such ecological changes and their effects. Most of the retrospective analyses conducted by NOAA Fisheries on other ecosystem components date back only to the mid-1980s; to fully evaluate this question, we need observations from before the purse seine fishery began to impact populations of dolphins. This is not a criticism of the research program conducted by NOAA Fisheries, merely a reflection of the remote location, vast size and trophic complexity of this tropical marine ecosystem.

Nevertheless, it is possible to review some of the ecological changes that could have occurred over the past half-century in the ETP and to provide advice regarding the likelihood that such changes have had a substantial effect on the dynamics of dolphin populations. Below, I discuss some ecological mechanisms that could affect the recovery

of depleted dolphin stocks in the ETP and discuss their likelihood, based on the available evidence.

El Niño-Southern Oscillation Events

Climatic variation can have significant, and sometimes unexpected, consequences for the dynamics of exploited animal populations. Thus, it is conceivable that such variation could have a significant impact on populations of dolphins in the ETP. This variation occurs over seasonal, inter-annual and inter-decadal time scales. Inter-annual variation in climatic patterns can have far-reaching consequences for the animal populations. For example, the North Atlantic Oscillation (NAO) causes fluctuations in temperature and rainfall over much of the North Atlantic Basin. Variation in the NAO, and subsequent changes in winter temperatures and rainfall, have important consequences for the dynamics of many species, ranging from cod to sheep.

Has inter-annual climatic variation occurred in the ETP at a scale that could result in a substantial effect on the population growth of dolphin populations? The strongest signature of climatic variation in the ETP is that of the El Niño-Southern Oscillation (ENSO), which occurs at intervals of two to seven years. The variation due to ENSO events appears to be considerably greater than that due to seasonal or inter-decadal variation.

Could ENSO events suppress or enhance the population growth rates of ETP dolphins? ENSO events are known to cause decreased growth rates, reproductive failure and increased rates of mortality in other marine mammals and in some seabirds. These effects occur because prey populations move, disperse, or suffer mortality and thus the foraging success of upper trophic level predators, such as marine mammals and seabirds, is depressed. There is some evidence from the NOAA Fisheries research program that populations of prey fishes and squids are depressed during El Nino events, but recover quickly in succeeding years. Thus, it is conceivable that pelagic dolphins in the ETP experience reduced foraging success during ENSO events and that, in turn, this reduced foraging success might have an effect on their demography.

It is also possible that ENSO events could have a positive effects on populations of dolphins in the ETP, by expanding the area of suitable warm habitat, reducing populations of competitors, or other factors. Not all species of marine mammals and seabirds are adversely affected by ENSO events. Almost all evidence regarding the effects of ENSO events on marine mammals and seabirds has been obtained from coastal populations, generally from land-based observations of breeding rookeries. And even in species for which such effects have been documented, they are generally transitory and populations recover quickly.

Thus, we simply do not know how populations of pelagic dolphins in the ETP respond to ENSO events. In fact, with our current state of knowledge, we cannot even predict whether such events are likely to have an adverse or positive effect on these populations.

Even with this paucity of information, however, it seems unlikely that individual ENSO events, even severe ones, could have significant long-term effects on dolphin populations. These populations have evolved in a system in which such events are commonplace; each individual dolphin will experience several events in its lifetime. Even if there are short-term effects on the growth or reproductive success of individual dolphins, these effects are unlikely to have long-term consequences for the dynamics of these populations. In conclusion, it is unlikely that individual ENSO events could change the carrying capacity of the ETP for dolphin populations in any significant fashion.

Inter-decadal variation

It is possible that climatic variation on an inter-decadal scale could change the carrying capacity of dolphin populations in the ETP. Given the slow life histories (long lives, low reproductive output, etc.) of these animals, such inter-decadal changes have the potential to affect their population dynamics in a significant manner. There is now widespread agreement within the scientific community that, at least in some areas, inter-decadal climatic variation can significantly alter the structure of marine ecosystems. These longer-term changes, sometimes referred to as regime shifts or phase changes, may have significant effects on the structure of entire ecosystems and on the dynamics of their components. For example, such inter-decadal changes in ocean climate (the Pacific Decadal Oscillation) are now held to be responsible for large-scale changes in the structure of coastal ecosystems in the North Pacific, with important consequences for upper trophic level predators such as marine mammals and birds.

Inter-decadal changes may also have occurred in the ETP, but our ability to detect them is limited by the relatively short-time series of observations of the physical and biological oceanography of the region (with the exception of sea surface temperature). The magnitude of this inter-decadal variation, if it has occurred, is markedly less than that documented for other areas. Since the mid-1970s, for example, there have been trends of surface warming and a more shallow thermocline. This variation is considerably less than that caused by ENSO events. Nevertheless, subtle changes in the oceanic environment over such long time scales could have important effects on the structure of the ETP ecosystem and on the demographics of dolphin populations.

It is possible, for example, that slight changes in the depth of the thermocline could make mid-water prey more or less available to dolphins. Such an effect might have long-term repercussions for the foraging success of individual dolphins. Alternatively, if such a regime shift was accompanied by more frequent ENSO events, it is conceivable that the increased frequency of such events, combined with the decreased duration of intervening periods, could have a cumulative impact on the carrying capacity and demography of dolphin populations.

There is little, if any evidence, for the existence of such ecological effects in the ETP, however, and it is still unclear whether such inter-decadal regime shifts have occurred there. Nevertheless, it should be noted that the paradigm of inter-decadal regime shifts has been developed only recently, in well-studied coastal areas with long time series of

observations. It is entirely conceivable that a relatively subtle, but ecologically important, regime shift has occurred unnoticed in the ETP.

Unfortunately, we do not have a sufficient time series of data from other upper trophic level organisms with which we might draw inferences regarding the effect of such a regime shift. The data sets for seabirds and other cetacean species extend back only to the mid-1980s. As noted by one of the other panelists, all of these observations have been made within one 'phase' of Pacific Decadal Oscillation. Thus, if profound changes in ecosystem structure had occurred over a period of several decades, we would not necessarily expect to see evidence of their effects with the data at hand.

So, as for climatic variation on the inter-annual scale, it is not possible to draw firm conclusions regarding the existence of such regime shifts in the ETP, nor on their effects on dolphin population biology, should they have occurred. Nevertheless, I believe that it is unlikely that such regime shifts have had a dramatic effect on the carrying capacity of this environment for spinner or spotted dolphins. The number and biomass of dolphins and tunas, important upper trophic level predators in the ETP, have been reduced considerably by fishery activities over the past 50 years. Thus, if their populations respond as do most other stocks of exploited animals, there should be surplus prey in the system, allowing for population growth and recovery once harvesting pressures were reduced. Given the scale on which dolphin populations were depleted, even moderate climatic effects on prey would not be expected to adversely affect their rates of population growth. As noted above, however, it is not possible to eliminate inter-decadal climatic variation as a significant factor in the demographics of these populations, given the available time series of observations.

Other ecological changes

It is also possible that the structure of the ETP ecosystem has changed in ways that could significantly affect the dynamics of dolphin populations. In Alaska, for example, sea otter populations are experiencing dramatic declines in abundance in the absence of harvest pressure. Although the factor or factors causing these declines is not yet fully understood, some scientists have postulated that predation by killer whales is responsible. It is hypothesized some killer whales have only recently switched to feed on sea otters, after dramatic declines in populations of other mammalian prey, notably Steller's sea lions and harbor seals. Ultimately, such declines in pinniped and otter populations have been linked to the over-harvest of baleen whales in the North Pacific, which may have been important prey of killer whales prior to the advent of industrial whaling in this area. This is a controversial hypothesis and one that does not yet have wide support within the scientific community, but I raise it here to illustrate the complex nature of interactions among populations of mammalian predators and their prey in marine ecosystems.

It is conceivable that similar changes have occurred in the ETP, although we have no evidence indicating that this is the case. In fact, with our present level of knowledge, we cannot even identify the full suite of predators or competitors of dolphins in the ETP. For those species that are known to prey on dolphins, or that exhibit dietary overlap with

them, we do not have sufficient time series with which we could even begin to address such hypotheses. So, once again, limitations on our knowledge prevent us from drawing any conclusion regarding the likelihood of the existence of such ecological changes.

Conclusions

It is not possible to assess whether significant changes in the ETP ecosystem have affected the dynamics of dolphin populations over the past fifty years, either by modifying carrying capacity or through other processes. We simply do not have a sufficient understanding of the dynamics of this system, nor do we have time series of observations that are long enough to assess the probability that such changes have occurred. It is clear that no dramatic changes have occurred since the mid-1980s, but this observation does not preclude the possibility that significant changes occurred before that time.

However, I recognize that a scientific finding of 'insufficient knowledge' is not particularly helpful in this instance. It is my opinion, after considering the scientific findings of the NOAA Fisheries research program, that *it is unlikely that the ecological structure of the ETP has changed substantially in a way that could significantly impede or promote the population growth of depleted dolphin stocks*. I base this opinion on the following observations.

Stocks of northeastern spotted dolphins and eastern spinner dolphins have been reduced to approximately 20% and 35% of pre-fishery levels, respectively. In addition, the populations of tuna, billfish and other large predators have also been reduced by fisheries in the ETP. During this period, however, there has been no fishery for the mesopelagic or epipelagic prey of these predators. Thus, a large component of the biomass of upper trophic level predators has been removed from this system, without any anthropogenic perturbation of their prey base. In this complex, tropical marine ecosystem it is reasonable to assume that upper trophic level predators were resource limited prior to exploitation. Following such dramatic reductions in abundance, predators should exhibit a significant density-dependent response, particularly once the source of mortality has been largely removed. We see no such effect with populations of northeastern spotted and eastern spinner dolphins. Even if moderate changes in the structure of this ecosystem occurred over the past fifty years, I would still expect to see population growth rates at or near their maximum values for these two highly depleted stocks. The lack of a response in population growth by both species is troubling and suggests to me that it is more likely that factors other than ecosystem changes are involved. As noted in the Science Report, the carrying capacity of the ETP would have to have been reduced by approximately 80% and 65%, for northeastern spotted and eastern spinner dolphins respectively, to explain the lack of population growth observed during the past two decades. Nevertheless, as noted throughout this report, it is not possible to dismiss the possibility that ecosystem changes have significantly affected the population growth rates of these dolphin stocks.

I hope that these comments are useful. I would like to thank the staff of NOAA Fisheries for their assistance in the preparation of this report.

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